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CONFIDENTIAL

THIRTY-FIFTH

PROGRESS REPORT

OF

THE FIRESTONE TIRE & RUBBER CO.

ON

BATTALION ANTI-TANK PROJECT

Contract Nos.
DA-33-019-ORD-33 (Negotiated)
DA-33-019-ORD-1202

RAD Nos. ORDTS 1-12383
ORDTS 3-3955
ORDTS 3-3957
ORDTA 3-3952

THE FIRESTONE TIRE & RUBBER CO.
Defense Research Division
Akron, Ohio

JUNE, 1953

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INDEX

ABSTRACT

An inventory of T137 rifles and T152 mounts, manufactured by Firestone, is given.

A review is made of the development of the T52E2 and T53E1 shell cases. A specific problem of the bulging of non-heat treated shell cases lead to an investigation of the feasibility of localized heat treating using induction heating. The data from the investigation are presented and discussed.

Thirty-eight rounds of T119 folding fin projectiles were fired to investigate the effect of the number of fins upon the accuracy of the projectile. The test results are given.

A portion of a larger program concerning projectile yaw and the effect of muzzle blast on accuracy of the T119 projectile, is reported.

In the penetration study program, tests were made to extend the use of data for the 105mm cones and charges to other sizes. To implement this, scale studies were made to determine the effect of size upon penetration. The test data are presented and analyzed.

THE WEAPON SYSTEM

An inventory of T137 rifles and T152 mounts manufactured by Firestone for its own research and development activities is given in Table I.

Table I

Inventory of Recoilless Rifles and Mounts

Manufactured by Firestone and Used in Research and Development Activities of Defense Research Division

Rifle or Mount	Location	Comments
RIFLES		
T137E3 Rifles		
Serial Nos. 1 & 2	Akron	Returned from Fort Benning
No. 13	Aberdeen Proving Ground	Test Facility
Nos. 21 & 22	Akron	For Spare Parts
T137E2 Rifles		
Serial No. 1	Akron	For Spare Parts
No. 2	Erie Ordnance Depot	Test Facility
T137E1 Rifles		
Serial No. 4	Watertown Arsenal	Metallurgical Study
No. 8	Akron	Held for historical value
MOUNTS		
T152E5 Mounts		
Serial Nos. 1 & 2	Akron	
No. 3	Aberdeen Proving Ground	
(Rifles and mounts scrapped have been dropped from inventory. For complete accounting see Thirty-Second Progress Report)		

Induction Heat Treated Shell Cases

A preliminary report of the performance of seventeen T53E1 shell cases which had been heat treated over a localized area by induction hardening and tempering was presented in the Thirty-Fourth Progress Report. A complete report of this development is presented here.

Two meetings held in Office, Chief of Ordnance (ORDTS and ORDTA) on August 8 and 16, 1952, were concerned with the BAT project and resulted in certain decisions regarding standardization of the weapons and ammunition. It was requested that the BAT rifle, T137, be modified so as to be capable of firing all types of BAT ammunition i.e., the ammunition developed for the T170 and M27 rifles as well as that developed specifically for the T137. In addition, a decision was made that in each of the several possible "packages" of ammunition (HEAT, HE, HE-P, WP) only the HEAT round could be finned and that the others must be the more conventional spinning rounds.

In order to comply with these revised requirements it was necessary to make extensive changes in the chamber of the T137 rifle, so that it could accommodate the other types of ammunition. The regular ammunition uses the M32 cartridge case. This case was in production, was readily available, and could be modified easily for use in the T137E3 rifle. Because the pressures in the BAT rifles are higher than in the M27 rifle, for which the M32 case was developed, it was found necessary to heat treat the M32 cartridge cases. Two modifications of the M32

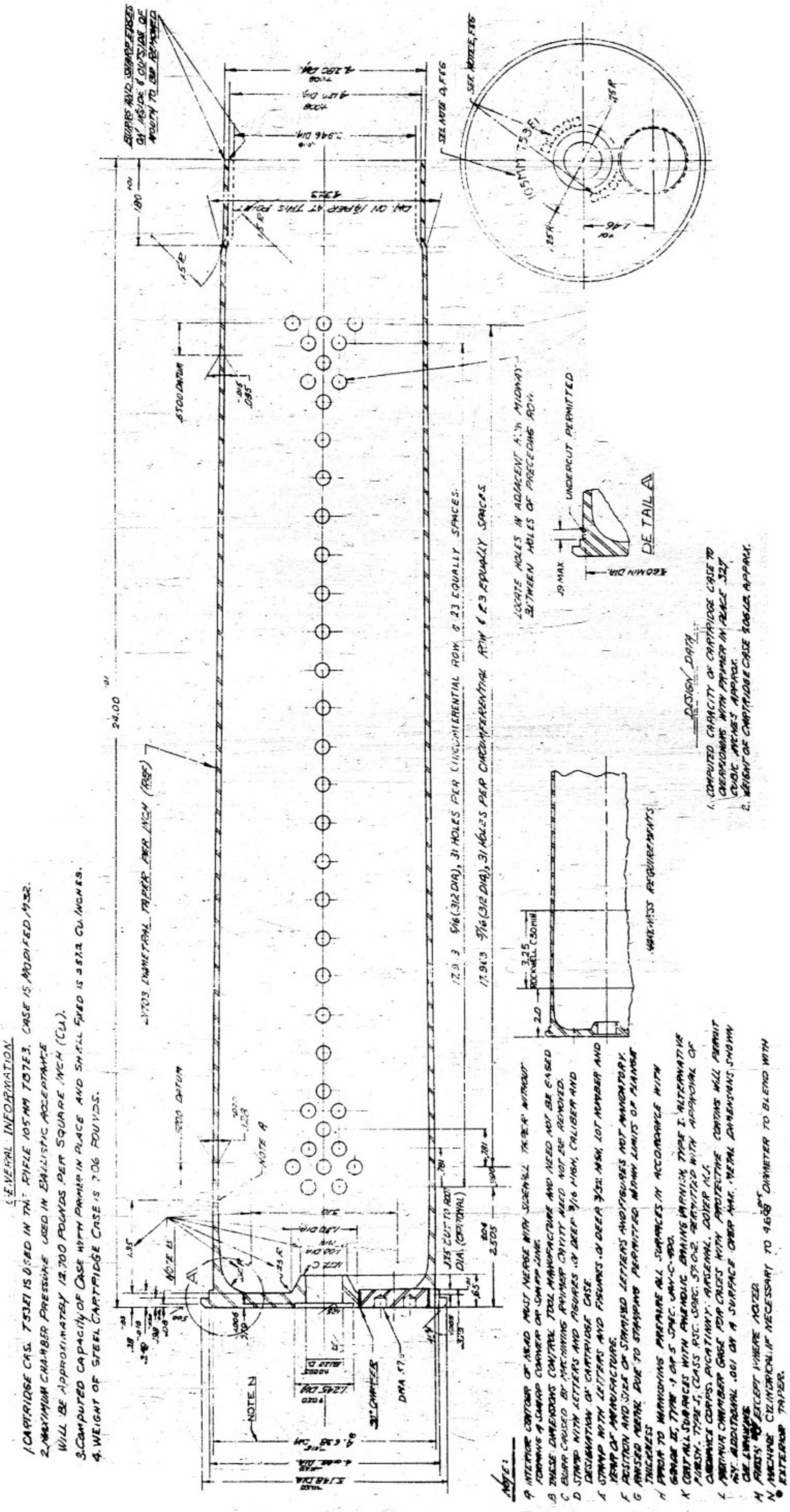

Fig. 1. Drawing of T53E1 Cartridge Case.
T52E2 Variation Also Shown.

case, designated T52E2 and T53El are as follows:

T52E2 - Standard mouth, heat treated, enlarged primer counterbore, for use with conventional spinning ammunition.

T53El - Expanded mouth, heat treated, enlarged primer counterbore and plug in the base for rear loading, for use with the T119E11 HEAT round.

Figure 1 is a drawing of the T53El case. The smaller mouth of the T52E2 case (standard size for the M32 case) is indicated by the dashed lines. When used without heat treating about 50% of these cases bulge with a 100% charge and all fail at a 115% charge. When hardened to Rockwell C 30 to 35 the cases are satisfactory at a 115% charge (See Table IV of the Twenty-Sixth Progress Report). In this experiment the cases were quenched and tempered in a neutral salt bath to the desired hardness. While this procedure eliminated the case failures, it has proved to be cumbersome and has the disadvantage that final machining and sizing must be done on the hardened case.

It was observed that the bulging of the case was limited to a zone approximately two inches in length extending forward from a point about 2.5 inches from the base. Accordingly, it was proposed that the heat treatment of the case be limited to the area where bulging occurred, leaving the balance of the case in its "as drawn" condition. It was recognized that the required hardness could be obtained by induction heating methods, but that there would be a transition zone at each end of the hardened area where the case would be, in effect, "process annealed" due to the temperature gradient. The extent and degree of this softened portion, and its effect upon performance, were not known. Furthermore, the effect of the cartridge case perforations upon the induced heat pattern and upon the heating efficiency had to be determined.

Twenty-five cases from a shipment of M32 cases were selected for evaluation of the induction heating method. Arrangements were made with the Metallurgical Laboratory of the Tocco Division, The Ohio Crank Shaft Company, to make an inductor and to induction harden the experimental cases. Figure 2 is a sketch of the inductor which was used. The pertinent operating data were as follows:

Frequency	3000 rps
Power	130-100 KW
Heating Time	10 sec
Delay Time	5 sec
Quench Time	15 sec (Water)
Quench Pressure	2.5 lbs.
Rate of flow	75 gpm
Temperature of Quench	80°F
Type Steel	AISI 1030
Tempering	one hour at 700°F

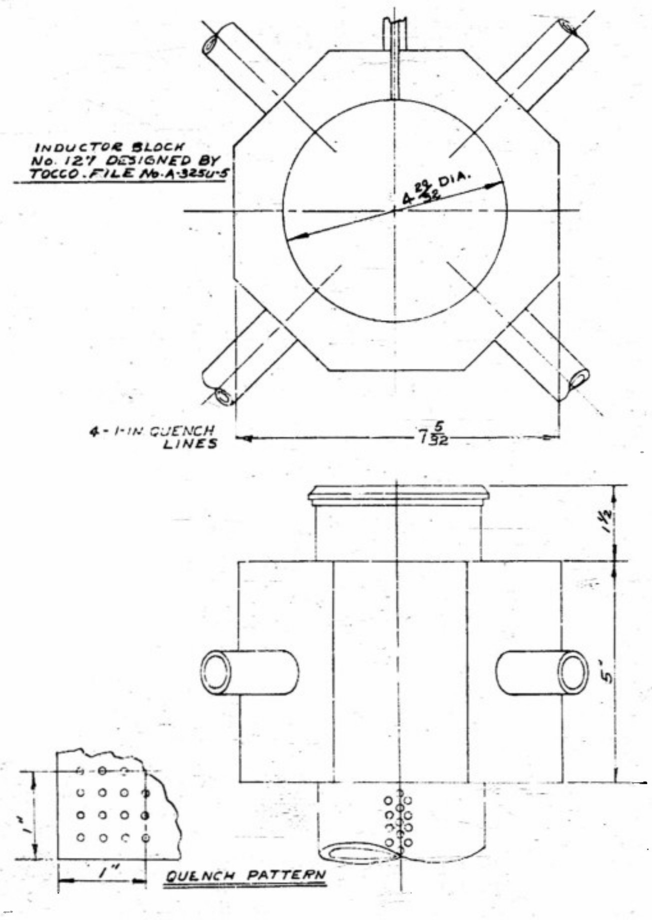

Fig. 2. Inductor Block For Induction Hardening Perforated Shell Case.

After developing the above procedure, seventeen cases remained from the original twenty-five. The hardness of these cases was measured after hardening and the data are shown in Figure 3. These data are in agreement with the results of hardness measurements made by Tocco on longitudinal strips cut from the hardened zone.

Ten of the seventeen cases were used for firing tests at Erie Ordnance Depot. The firing record for these ten cases is shown in Table II. After each case had been fired once the lot were returned to Akron for inspection. No evidence of bulging or distortion was noted. All seventeen cases were then returned to Erie Ordnance Depot for use in routine firing. A record of the firings for each case was kept until each case had been used five times. One case bulged on the second firing with a 100% charge, but all other cases have been used a minimum of six times each with at least one 115% charge in each case and none has failed.

As a result of these tests it is concluded that:

1. Locally hardening and tempering a 5 inch zone, beginning at a line 2 inches above the base, to a hardness of R_C 30 to 36 will produce a case which will not bulge at a 115% charge.

2. The induction method of heating is practical. The distortion of the flux, caused by the case perforations, does not greatly affect the process.

3. The transition zones were quite narrow, approximately .25 inch long, and although softer than the balance of the case do not themselves cause failure of the case.

4. The short duration of the heat treating cycle should speed up the heat treating operation and the localized hardening should reduce the cost of the subsequent machining operation.

It is believed that this method of heat treating cases is applicable to the large scale production of high strength cases and should result in substantial savings compared with the use of heavier wall cases, higher strength steels, or heat treatment of the entire case.

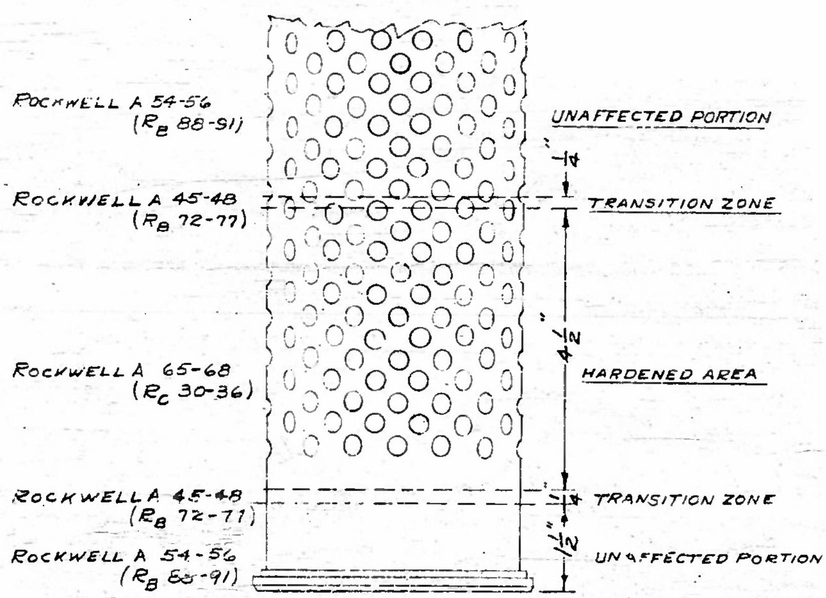

Fig. 3. Hardness Pattern.
For Induction Hardened T53E1 Cartridge Case.

Table II
Test Firing Data
T52E1 Cartridge Case

Date of Test Feb 13, 1953

Purpose of Test Shell Case Program T52E1

PROJECTILE

Model T119
Type Slug DRC-510
Weight 17.5 lbs (Nom)
C.G. Location —
Bourrelet Dia 4.132 −.002
Special Features No band

TEST GUN

Model T137E3
Type 105mm Recoilless
Serial No #1
Chamber 22B-775 B
Bushing (Vent) 22-B-A2-X-A
Tube 22B-849 C, 105 in, 1 in 20 Twist
Sighting Equipment M17 Adapted Telescope
Mount
Type Pendulum
Constant 2.25 lb sec/in
Solenoid Mechanical firing system

MISCELLANEOUS DATA

Range —
Propellant
Type MP M10 Web .0315 Weight —
Lot No PA 30240
Primer M57
Shell Case —
Liner T6, rayon & polyethylene
Temperatures
Magazine Max 75°F Min 70°F Present 70°F
Loading Room 75°F Ambient 28°F

Round No	Powder Depth in Case	Proj Weight (lb.)	Powder Charge (lb - oz)	Recoil (in)	Chamber Pressure (lb/sq in)	Per cent Pressure		Elev (mils)	Case No.	Position of Hit Vert	Position of Hit Horiz	Corrected Position of Hit — mils Vert	Corrected Position of Hit — mils Horiz	Recoil (in)	Observations
4471-1	4 3/4	17.22	7 14	4 1/4 F	10,600 / 11,900	100			1						
4472-2	4 3/4	17.27	7 13	1 1/2 F	11,700 / 13,100	100			7						
4473-3	5 3/8	17.34	7 11	? R	10,600 / 13,700	100			11						
4474-4	5 1/2	17.30	7 11	1/2 R	12,600 / 13,100	100			15						
4475-5	5 3/8	17.24	7 11	0	[illegible]	100			14						
4476-6	5	17.35	8	1 F	12,300 / 13,750	115			16						
4477-7	5	17.26	8	1/2 F	13,600 / 14,600	115			17						
4478-8	4 7/8	17.28	8 2	1/2 F	12,900 / 13,900	115			2						
4479-9	5 1/8	17.27	8 2	? F	12,400 / 13,600	115			6						
4480-10	5 1/8	17.30	8 2	1/4 F	12,700 / 13,500	115			9						

Note: None of the 10 shell cases showed any visible signs of bulging.
All rounds were loaded and fired as single units.
Powder charge was decreased after round 2 because of high pressures.
Powder charge was increased after round 7 because of low pressures.

Proof Director E. Huffman
Observers L. Swaebly, C. Miller
M. Toohig

Signed R. McLeon

Effect of Number of Fins

Three lots of T119 projectiles, each having either four, five or six fins, have been fired for accuracy. The target was 18 ft by 18 ft and was placed at a range of 1055 yards. The data are presented in Table III and are summarized below.

No. Fins	No. Rounds	Hits	Misses	Probable Error (mil) Horiz.	Vert.
Four	13 (a)	7	4	±.92	±.53
Five	15	13	2	±.61	±.64
Six	10	10 (b)	0	±.49	±.33

Notes:

(a) Two rounds fired for observation only.

(b) One round struck velocity coil before striking target and was not used in calculation of probable errors.

The four-finned projectiles not only had a considerably higher horizontal probable error of dispersion than the other types but three of the four misses and the two rounds fired for observation were observed to fly erratically. The data indicate that the T119 with four fins is marginally stable, and no further testing of this type of projectile is planned.

The two misses in the group of projectiles with five fins were observed to have good flight. The accuracy obtained for this group was not as good as that of the six-finned projectiles but is not so poor as to suggest a discontinuation of the testing of this type. The gun used in the above test has a forward recoil and further testing is planned with a gun adjusted to give a rearward recoil.

Spin Measurements

Projectile spin rate was measured as part of a more comprehensive program to study projectile yaw and to evaluate the effect of muzzle blast on the accuracy of the T119E11 projectile. The complete data have not been analyzed and only spin measurements are presented here.

For the purpose of determining spin a series of nine yaw card frames were placed at distances varying from 30 ft to 288.74 ft in front of the T137E2 gun. Five rounds were fired through cardboard yaw cards with the cards being replaced after each round. A horizontal reference line on each yaw card and a small pin pressed into one of the fins of each projectile were used in recording the rotation of the projectile between successive cards.

The details of the range data are presented in Table IV. The yaw card measurements are shown in Table V and Fig. 4 is a plot of the rotation versus distance from the gun. The smoothed curves were used to determine the rolling velocity as shown in Table VI and Fig. 5. To determine the muzzle spin, the spin induced on the projectile by friction in the gun bore, the spin rate curves (Fig. 5) were extrapolated to the muzzle and it was found that the projectile emerges from the muzzle with a spin rate of one to two revolutions per second. Analysis of the spin data is being continued to provide an equation which will describe the roll motion of the T119 projectile throughout its entire range.

Table III
Accuracy Range Data
To Test Accuracy of Four- and Five-Finned Projectiles
T119 Folding Fin Projectile

Date of Test June 12, 1953

Purpose of Test To test Accuracy of 4 & 5 finned projectiles

PROJECTILE
Model T119
Type F.I.I. & F.X
Weight
C.G. Location
Bourrelet Dia 4.132 - .002
Special Features F.II standard
4X 4 & 5 fins

TEST GUN
Model T137E2
Type 105 mm Recoilless
Serial No
Chamber 6-B-637
Bushing [illegible] 22-A-269 BE
Tube 22-B-849 C
Sighting Equipment M62 E4, #18006 & Gunners Quadrant M1, #78241
Mount
Type T152E4 (on concrete base)
Limit = 3798 in
Solenoid Mechanical Firing System
Internal M3

MISCELLANEOUS DATA
Range 1055 yds
Propellant
Type MP M10 Web .0335 Weight 7 lbs 12 3/4 oz
Lot No RA 30239
Primer T.B.I.
Shell Case T53
Liner 1.52 polyethylene (base cut off)
Temperatures
Magazine
Max 70°F Min 70°F Present 70°F
Loading Room 76°F Ambient 85°F

Round No	No. of Fins	Proj Weight (lb)	Proj No	Wind Vel mph	Wind Dir degrees	Chamber Pressure (lb/sq in)	Muzzle velocity ft/sec Instr	Muzzle velocity ft/sec Actual	Elev (mils)	Azimuth (mils)	Position of Hit (inches) Vert	Position of Hit (inches) Horiz	Corrected Position of Hit mils Vert	Corrected Position of Hit mils Horiz	Recoil (in)	Observations
5094	6F	17.56	X356	9	-210	9500	—	—	25.0	1 L	+72	-13 1/2	+.474	+.592		Apparent good flight
5095	6F	[illegible]	X382	[illegible]	215	9600	—	—	23.5	1 L	-38	+14 1/4	-1.000	+1.323		do
5096	5F	17.30	X622	7.5	-210	10,200	1639	1665	23.5	1 L	+7 1/4	-20	+.191	+.421		do
5097	4F	17.07	X599	10	195	10,300	1658	1684	23.5	1 L	—	—	—	—		Missed target, swerved left at approx 700 yds
5098	6F	17.52	X393	10	-220	10,200	1642	1668	23.5	1 L	-1	+42 1/2	-.026	-.171		Slight yaw
5099	5F	17.31	X621	12	235	10,100	1664	1690	23.5	1 L	+31 1/2	-52	+.829	-.421		Apparent good flight
5100	4F	17.06	X594	7.5	-240	9,800	1670	1696	23.5	1 L	-45 1/2	+57 1/2	-1.198	.566		do
5101	6F	17.52	X388	10	-235	10,100	1666	1692	23.5	1 L	+8 1/4	-17	+.217	+.500		do
5102	5F	17.32	X264	10	-240	10,100	1673	1699	23.5	1 L	+43 1/2	+47 1/2	+1.145	+2.199		do
5103	4F	17.06	X595	10	240	10,000	1684	1710	23.5	1 L	+11 1/2	+41 1/4	+.303	+2.192		do
5104	6F	17.52	X381	9	230	10,000	1651	1677	23.5	1 L	-15 1/2	+9 1/2	-.408	+1.198		do
5105	5F	17.31	X627	8	-220	10,000	1666	1692	23.5	1 L	+45	+31 1/2	+1.185	+1.777		do
5106	4F	17.01	X592	7	-225	9,900	1666	1692	23.5	1 L	+30	+32	+.790	+1.790		do
5107	6F	17.52	X386	6	255	—	1646	1672	23.5	1 L	-29	-2 1/4	-.764	+.889		do
5108	5F	17.38	X620	6	-260	10,600	1663	1689	23.5	1 L	+39	+12	+1.027	+1.264		do
5109	4F	17.06	X597	9	-255	10,400	1664	1690	23.5	1 L	+9 1/4	-4 1/2	+.244	+.829		do
5110	6F	17.52	X377	6	-225	—	1656	1679	23.5	1 L	-108	+34	-1.696	+1.843		Fin cut [illegible] good flight. Not included in P.E.
5111	5F	17.19	X619	6	-235	—	1628	1654	23.5	1 L	—	—	—	—		Missed target (over), apparent good flight
5112	4F	17.08	X59[illegible]	4	290	—	1642	1668	23.5	1 L	-15 1/2	+14 1/2	-.408	+1.330		Apparent good flight
5113	6F	17.52	X384	8	16	—	1630	1656	23.5	1 L	-5	-72	-.132	-.948		do
5114	5F	17.30	X612	7	-5	—	1633	1659	23.5	1 L	+4	+54 1/2	+.105	+2.383		do
5115	4F	17.08	X589	7	-5	—	1641	1671	23.5	1 L	-25	+75	-.658	+2.923		do
5116	6F	17.52	X390	8	15	—	—	—	23.5	1 L	-18 3/4	-38 1/4	-.494	-.059		do
5117	5F	17.30	X626	7	-5	—	1629	1655	24.0	1 L	-24 1/2	+44	-1.119	+2.106		do
5118	4F	17.03	X593	6	-30	—	1636	1662	24.0	1 L	—	—	—	—		Not observed

page 1 of 2

Table III (Cont.)

Date of Test June 12, 1953

Purpose of Test: Accuracy test of 4 & 5 fin projectiles

PROJECTILE
Model T119
Type [illegible] 4 FX
Weight —
CG Locat. in. —
Bourrelet Dia 4.132
Special Features E11 Standard, Ex 4 & 5 fins

TEST GUN
Model T137E2
Type 105mm Recoilless
Serial No —
Chamber 6-B-637
Bushing (Vert) 22-B-269 BE
Tube 22-B-849-C
Sighting Equipment M42E4 #18036 & Gunners Quadrant, M1, #78261
Mount
Type T152E4 (on concrete base)
[illegible] 37.98 in
Solenoid Mechanical Firing System

MISCELLANEOUS DATA
Range 105.5 yds
Propellant
Type M2-M10 Web .0335 Weight 7 lbs 12 1/4 oz
Lot No PA 30239
Primer [illegible]
Shell Case [illegible]
Liner [illegible] polyethylene (base cut off)
Temperatures
Magazine
Max 70°F Min 70°F Present 70°F
Loading Room 76°F Ambient [illegible]

Round No	No. of Fins	Proj Weight (lb)	Proj No.	Wind Vel mph	Wind Dir degrees	Chamber Pressure (lb/sq in)	Muzzle Velocity ft/sec Instr	Muzzle Velocity ft/sec Actual	Elev (mils)	Azimuth (mils)	Position of Hit (inches) Vert	Position of Hit (inches) Horiz	Corrected Position of Hit — mils † Vert	Corrected Position of Hit — mils † Horiz	Recoil (in)	Observations
5119	4 F	17.51	X341	3	350	—	1620	1646	24.0	1 L	-12 3/4	-10	-.810	+.685		Apparent good flight
5120	5 F	17.30	X613	5	55	—	1633	1659	24.0	1 L	-13 1/2	+25	-.829	+1.606		do
5121	4 F	17.06	X601	6	30	—	1636	1662	24.0	1 L	—	—	—	—		Erratic flight
5122	5 F	17.30	X625	15	25	—	1631	1657	24.0	1 L	+31	36	+.342	0		Apparent good flight
5123	4 F	17.08	X602	5	30	—	1666	1692	24.0	1 L	-30	-62	1.264	-.685		do
5124	5 F	17.29	X611	6	35	—	1648	1674	24.0	1 L	-5	17	.606	+.500		do
5125	4 F	17.07	X600	6	45	—	1675	1701	24.0	1 L	—	—	—	—		Erratic flight, swerved right
5126	5 F	17.30	X615	4	50	—	1660	1686	24.0	1 L	—	—	—	—		Missed target, apparent good flight
5127	5 F	17.30	X618	4	60	—	1651	1677	24.0	1 L	-35	+40 1/2	-1.395	+2.014		Apparent good flight
5128	5 F	17.29	X610	5	-80	—	1644	1670	24.0	1 L	-5	-5 3/4	-.606	+.833		do
5129	5 F	17.30	X614	3	-110	—	1657	1683	24.0	1 L	-23 1/2	+3 1/2	-1.093	+1.040		do
											Yaw Card Hole Diameters 1	Yaw Card Hole Diameters 2	Yaw Card Fin Diameters 1	Yaw Card Fin Diameters 2		
5130	4 F	17.08	X606	3	110		1644	1670	24.0	1 L	4 1/8 x 4 1/8	4 1/8 x 4 1/2	10 1/8 x 10 1/4	10 1/8 x 10 1/8		Fired through Yaw Cards, Erratic flight
5131	4 F	17.06	X596	4	-290		1634	1660	24.0	1 L	4 1/8 x 4 1/8	4 1/8 x 4 1/8	10 1/2 x 10 1/4	10 1/2 x 10 1/16		Fired through Yaw Cards, Erratic flight

Note: Asterisks, (*) denote rounds which were not positively identified due to poor observation caused by heat waves, therefore only the one method of calculating P.E was used. (No wind or muzzle velocity correction).
† Corrected to 0 Azimuth and 23.5 mil elev.
Inspection of the muzzle of the tube after firing disclosed fin marks at 3, 9 and 12 o'clock. Marks were 4 to 8 in long.
Fastax pictures were taken of round 5114 (proj X612)

Type Projectile	Number of Rounds	Center of Impact (mils) Vert	Center of Impact (mils) Horiz	P.E. (mils) Vert	P.E. (mils) Horiz
4 Fins	7	-.32	+.77	.53	.92
5 Fins	15	-.08	+.26	.63	.61
6 Fins	9	.34	.50	.33	.49

Yaw Card Distances

Gun — 53.96' — 1st Yaw Card — 101.29' — 2nd Yaw Card

Proof Director J. Chaney
Observers E. Cl[illegible]
F. Mendez

Signed O. Miller

page 2 of 2

Table IV
Range Data
Launching and Flight Evaluation
T119 Folding Fin Projectile

Date of Test: June 3 & 4, 1953

Purpose of Test: T119 Accuracy (Launching & Flight Evaluation)

PROJECTILE

Model: T119
Type: F.U.
Weight: 17.52 lb
CG Location: 7 in from hinge pin
Bourrelet Dia: 4.132 − .002
Special Features: Standard with ogive
Retardation Factor: 0.195 ft/sec/ft

Gun — 156.25' — 44.46' — Coil Distances

TEST GUN

Model: T137E2
Type: 105 mm Recoilless
Serial No:
Chamber: 1-K-679
Bushing (Vent): 6-B-637
Tube: 22-B-849-C
Sighting Equipment: M626 4 Elbow telescope, Tel Mount T143 E9, Gunners Quadrant M1 #7A261
Mount
Type: T152 & concrete base

MISCELLANEOUS DATA

Range: 1055 yds. Line of fire 38°E of Mag. North
Propellant
Type: M2 M10, Web: .0235, Weight: 7 lb 12½ oz / 7 lb 13½ oz
Lot No: RH 30239
Primer: M1A1
Shell Case: T53
Liner: Polyethylene & Rayon Sleeve DRC 419.1
Temperatures
Magazine
Max: 70°F, Min: 70°F, Present: 70°F
Loading Room: 80°F, Ambient: 80°F

M3 Internal — 1 mil = 37.98 in. — Solenoid fired mechanically

Round No	Proj. No.	Proj Weight (lb)	Powder Charge (lb-oz)	Wind (a) Vel mph	Wind (a) Dir degrees	Chamber Pressure, (lb/sq in)	Muzzle Velocity ft/sec Instr	Muzzle Velocity ft/sec Actual	Elev (mils)	Azimuth (mils)	Position of Hit (inches) Vert	Position of Hit (inches) Horiz	Corrected Position of Hit − mils (b) Vert	Corrected Position of Hit − mils (b) Horiz	Normal Wind Component	Body Yaw at Target	Fin Measurements at Target	Observations
5061	X 353	17.52	7-13½	13	175°	10,000	Hit	coil	23	1 L	missed	target	—	—	8.9	—	—	
5062	X 367	17.51	7-13½	—	—	10,400	1671	1714	23	1 R	−16½	+38	+0.513	+0.053	—	4¼ × 4¼	10⅜ × 10⅜ × 10⅜	Fired June 3
5063	X 354	17.52	7-13½	—	—	9,800	1647	1690	23	1 R	+11	+69½	+1.237	+0.882	—	4¼ × 4¼	10½ × 10¼ × 10½	
5064	X 348	17.50	7-12½	24	230°	10,100	1635	1678	23	2 L	−10½	+5½	+0.671	+2.041	5.0	—	10⅝ × 10½ × 10½	
5065	X 350	17.51	7-12½	17	225°	9,400	1630	1673	23	2 L	−39½	−16	−0.097	+1.474	3.5	—	—	
5066	X 355	17.54	7-12½	25	240°	10,000	1630	1673	23	2 L	−74	+61	−1.001	+3.502	9.4	4¼ × 4⅜	10½ × 10½ × 10¾	
5067	X 361	17.52	7-12½	15	225°	10,500	1637	1680	24	2 L	+8½	−7	+0.2	+0.026	1.8	4¼ × 4¼	10⅝ × 10⅝ × 10½	
5068	X 364	17.53	7-12½	15	240°	10,200	1635	1678	24	2 L	+22½	+42½	+0.597	+3.015	5.6	4⅛ × 4¾	10½ × 10⅝ × 10½	1st yaw card
5069	X 368	17.52	7-12½	14	235°	10,500	1642	1695	24	2 L	−33	−21	−0.869	+1.343	4.1	—	—	2nd "
5070	X 365	17.52	7-12½	16	240°	10,500	1643	1686	24	2 L	+28½	+34½	+0.750	+2.804	6.0	4⅜ × 4¼	10½ × 10⅝ × 10⅝	3rd "
5071	X 362	17.52	7-12½	16	235°	9,700	1644	1687	24	2 L	+28½	16½	+0.750	+1.461	4.7	—	—	4th "
5072	X 370	17.54	7-12½	7	225°	10,200	1626	1679	24	2 L	+35½	17	+0.935	+1.448	0.9	—	—	5th "

Note: The first seven rounds were fired to range in on the target. Then the last five were fired through nine (9) yaw cards each. The gun was sighted in on the target, then the bore sight was used to set the yaw cards in place, the 9th put up first, then the 8th, etc. After the first yaw card was in place, a vertical line was put in line with the M626 4 direct sight line. Yaw cards for projectile X 364 were sighted in and measured from the center of the tape. All the rest were sighted in and measured from the left side of the vertical and top of the horizontal lines. Yaw card distances and numbers given below. Fastax pictures of projectile X 364 were taken.
(a) Wind direction given as degrees clockwise from North (b) Corrected to 0 azimuth and 24 mils Elevation

Gun — 30' — 30' — 10.75' — 10.25' — 29.67' — 10.71' — 9.25' — 26.75' — 131.36'
Card 1, 2, 3, 4, 5, 6, 7, 8, 9

Center of Impact: V = +.337, H = +.164 mils
Probable Error − Vertical: ±.484 mils
Probable Error − Horizontal: ±.762 mils
Rounds 5064 through 5072

Proof Director: ____
Observers: F. Clark
Signed: O. Miller

Table V
Yaw Card Measurements
T119 Projectile

Card	Feet from Muzzle	Angle of Roll Measured Clockwise from Horiz. Ref. Line				
		X 362	X 364	X 365	X 368	X 370
#1	30.0	101°	251°	151°	349°	123°
#2	60.0	116°	278°	166°	367°	142°
#3	70.8	124°	283°	173°	376°	151°
#4	81.0	129°	289°	175°	384°	160°
#5	110.7	154°	311°	196°	410°	186°
#6	121.4	164°	324°	204°	422°	199°
#7	130.6	171°	337°	208°	432°	210°
#8	157.4	196°	372°	229°	465°	247°
#9	288.7	376°	582°	358°	683°	479°

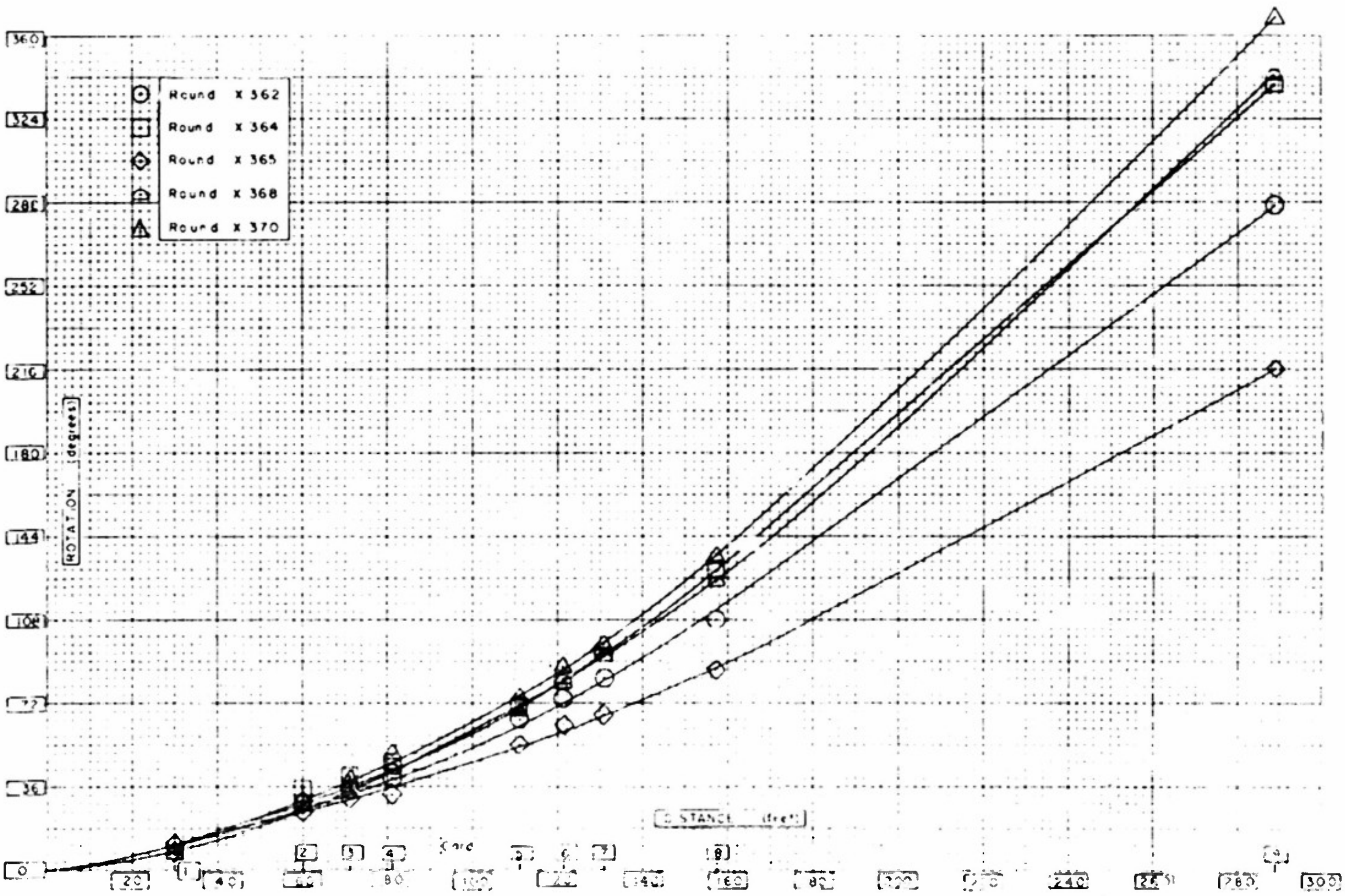

Fig. 4. Roll Angle Versus Distance From Gun.
T119E11 Projectile

Table VI
T119E11 Spin Measurements

Distance From Muzzle (Ft.)		20	60	100	140
Round X362	Velocity (fps)	1683.1	1675.3	1667.5	1659.7
	Rotation (deg./ ft.)	0.383	0.600	0.800	1.183
	(rps)	1.79	2.79	3.71	5.46
Round X364	Velocity (fps)	1674.1	1666.3	1658.5	1650.7
	Rotation (deg./ ft.)	0.450	0.658	0.900	1.400
	(rps)	2.09	3.05	4.15	6.42
Round X365	Velocity (fps)	1682.1	1674.3	1666.5	1658.7
	Rotational (deg./ ft.)	0.400	0.533	0.633	0.833
	(rps)	1.87	2.48	2.93	3.84
Round X368	Velocity (fps)	1681.1	1673.5	1665.5	1657.7
	Rotation (deg./ ft.)	0.367	0.700	0.983	1.300
	(rps)	1.71	3.25	4.55	5.99
Round X370	Velocity (fps)	1675.1	1667.3	1659.5	1651.7
	Rotation (deg./ ft.)	0.483	0.767	1.050	1.433
	(rps)	2.25	3.55	4.84	6.57

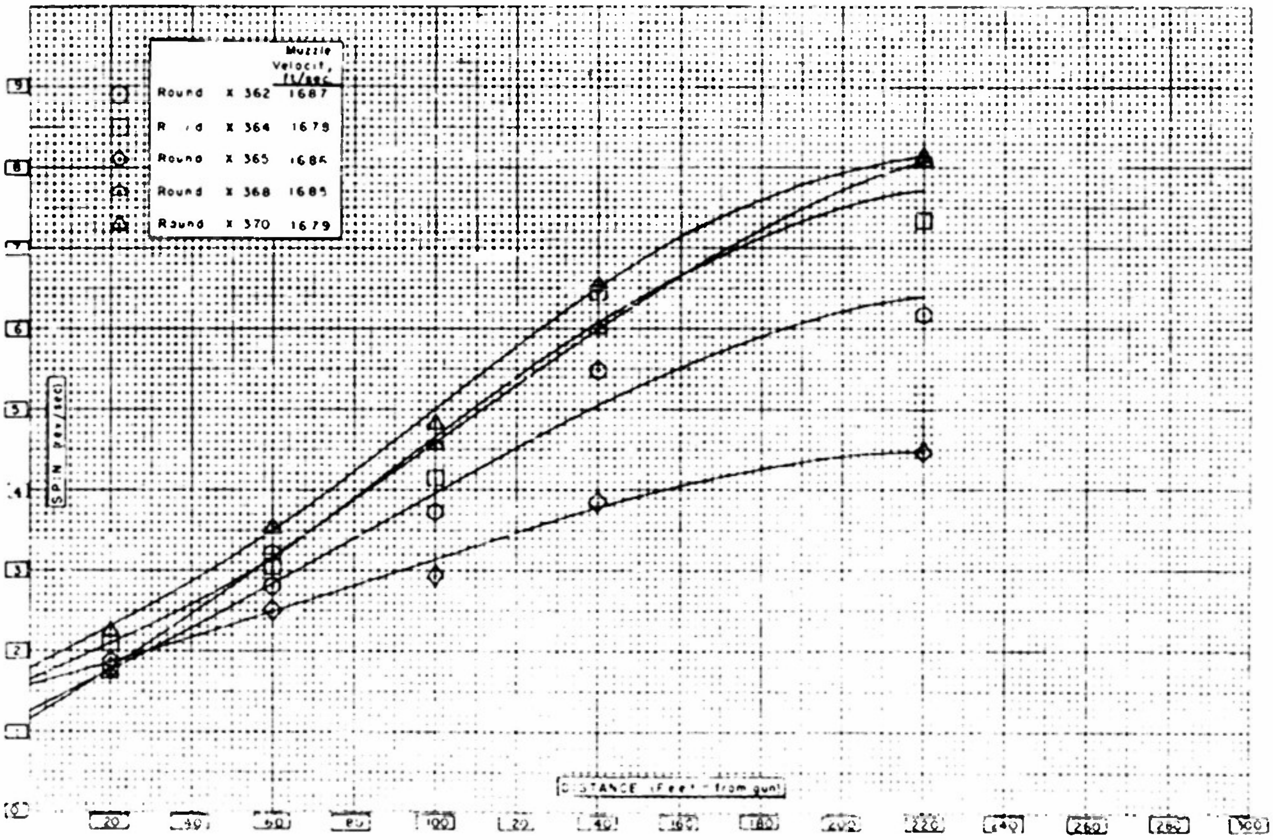

Fig. 5. Rolling Velocity Versus Distance From Gun.
T119E11 Projectile.

Future Program

1. Projectiles with zinc ogives have been assembled. It is planned to fire groups of these projectiles for tests of strength, accuracy, and penetration.

2. Twenty projectiles, each with a tail assembly shorter and stronger than that of the T119E11 projectile, have been assembled and will be test-fired.

3. A group of 20 T119E11 projectiles has been prepared to study the effect of relaxed dimensional tolerances in the fin assembly. These projectiles will be fired to determine both mechanical and flight behavior.

4. A program to improve the launching of the T119E11 projectile has been started. It is planned to study projectile behavior near the gun muzzle by means of yaw cards and photography.

5. The effect of ogive length upon the accuracy of the T119E11 projectile is to be determined by tests with both shorter and longer ogives. The projectiles are ready for assembly and tests should follow soon.

Scaling Studies

In extending the use of data for 105mm cones and charges to other sizes it is necessary to determine the effect of size upon performance. From theoretical considerations it appears that geometrically similar shaped charge rounds of widely differing diameter should behave similarly if the diameter "d" is taken as the unit length, (BRL Report 623, Section VI and the references given there). As applied to rotating charges it is to be expected that the relative deterioration in penetration caused by spin, for rounds of different diameter d spinning at ω radians per sec should be determined by the spin parameter ω d. Since a considerable amount of work has been done in this laboratory with DRB398 cones it is planned to evaluate similar charges scaled down in the ratio 75/105 and 90/105. The first tests with the 75/105 size charges have been completed.

The 75/105 scaled counterpart of the DRB398 cone and DRC376 test assembly consists of a DRB706 cone and DRC505 test assembly (No. 2 nose ring). Fig 6 shows the cone and Fig. 7 shows the cone and charge assembly. These cones were made from DRB398 smooth cones by cutting them off at the appropriate diameter (2.50-inch register diameter) and by machining out the inside cone surface to the desired final wall thickness (.071 inch). The only departure from linear scaling is in the small spitback tube whose dimensions are unchanged from the original DRB398 cone. In this scaling study the effect of standoff and rotation have been determined for the 75/105 charge and cone, and the data are to be compared with the corresponding data for the 105mm charge.

The penetration behavior of DRB398 smooth cones has been described in earlier reports. The effect of standoff is shown in Fig. 6 of the Thirty-Second Progress Report and the effect of rotation in Fig. 6 of the Twenty-Seventh Progress Report.

The inspection data for the DRB706 cones are shown in Table VII and the penetration data are shown in Tables VIII and IX and Figs. 8 and 9.

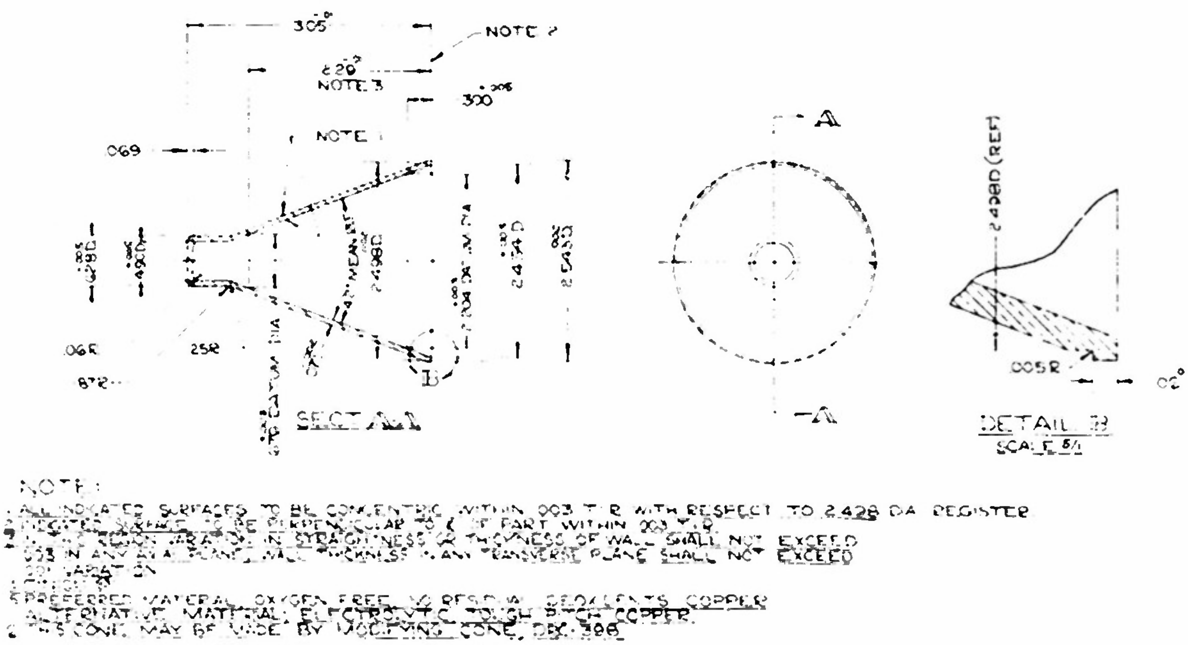

Fig. 6. DRB706 Cone.
Scaled Counterpart of DRB398 Cone.

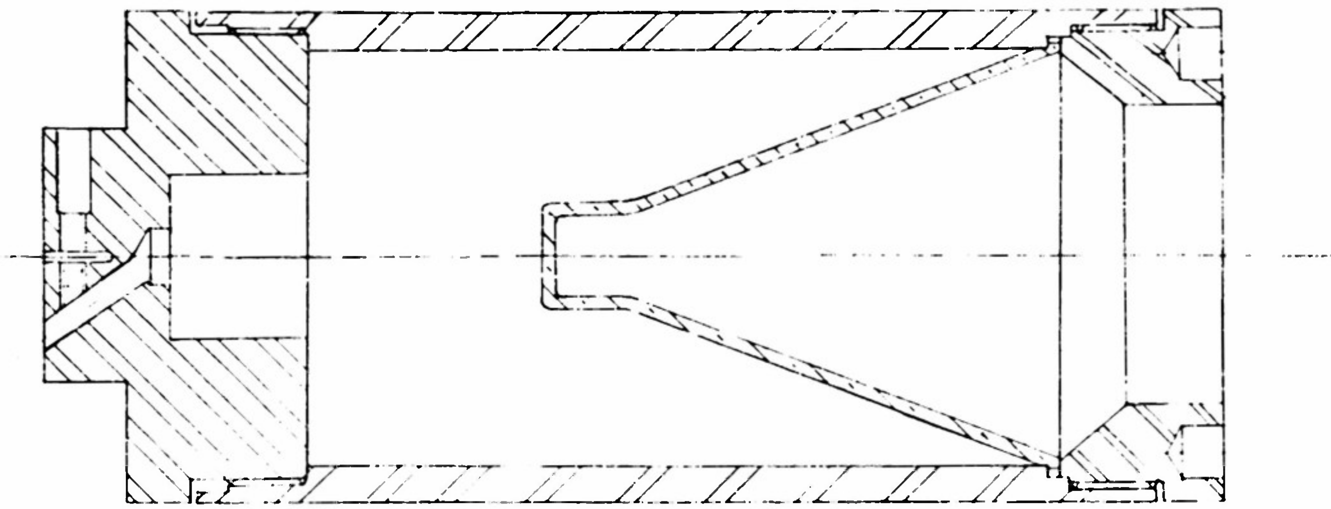

Fig. 7. DRC505 Penetration Test Assembly.
Scaled Counterpart of DRC376 Test Assembly.

Scaling Standoff

Fig. 10 is a generalized plot of the penetration standoff behavior of the type of cone and charge used in this study. Both penetration and standoff are expressed in terms of charge diameters and are therefore dimensionless quantities. As shown by this plot the one curve fits the observed data for both 3.5 inch and 2.5 inch charges quite nicely.

Scaling of the Rotational Effect

Fig. 11 shows the effect of rotation upon cones of this type. The data are plotted in terms of the "reduced" penetration and spin rate. The reduced penetration may be defined as the observed penetration at spin rate ω divided by the non-rotated penetration. The reduced spin rate is the spin rate expressed in terms of the relative linear surface velocity of the cone base - ωd. As expected the effect of spin is invariant under these transformations and the one curve fits the observed points for both 2.5 and 3.5 cones and charges well within the experimental error.

Future Program

1. Scaling Studies. Two series of scaling studies are planned. One series with simple apex copper cones is geometrically scaled to 75, 90 and 105mm. The other series uses DRB398 cones (with short spitback of constant size) with height and wall thickness adjusted to 75, 90 and 105mm size.

2. Cones Made of Zinc and Aluminum are to be tested for penetration. Penetrations approaching those of copper cones have been reported for certain aluminum and zinc alloys.

3. Composite Cone Study. A series of tests using copper cones with aluminum inserts will be tested.

a. .080-inch thick copper shell and .020 and .040-inch aluminum insert (24S-T4).

b. .100-inch thick copper shell and .020 and .040-inch aluminum insert (24S-T4).

c. Same as (a) and (b) but using 2S-F aluminum instead of 24S-T4.

d. Same as (b) but using two stamped 2S inserts in each cone.

e. Same as (b) except aluminum is sprayed (metalized) into inside of cone. Tests will include "as sprayed" and "sprayed and machined" samples.

4. Effect of Internal Tee Contour. Two new designs, in which the length of the .875-inch bore of the DRC314HW11 tee is shortened, are to be compared.

Table VII
Inspection Data
75 mm. DRB706 Smooth Cones

Cone No.	Wall Thickness (in.)			Maximum Variation in Wall Thickness (in.)		Max. Wall Waviness (in.)		Concentricity T.I.R.[1,2]		
	Max.	Min.	Avg.	Trans.	Long.	O.D.	I.D.	Base Datum	Apex Datum	Cone Tip in Ass'y
Specification DRB-706 Cones	.071	.069		.001	.003	.0030	.0030	.0030	.0030	.015 (Nominal)
FS1023	.078	.071	.0741	.001	.007	.0030	.0050	.0020	.0030	.003
FS1024	.080	.073	.0763	.002	.007	.0020	.0050	.0010	.0020	.002
FS1025	.080	.073	.0766	.001	.007	.0020	.0030	.0010	.0020	.006
FS1026	.077	.071	.0739	.001	.006	.0020	.0040	.0010	.0010	.007
FS1027	.078	.071	.0751	.002	.007	.0020	.0040	.0020	.0010	.004
FS1028	.082	.071	.0763	.002	.011	.0020	.0050	.0040	.0020	.004
FS1029	.077	.070	.0736	.001	.007	.0020	.0040	.0020	.0010	.013
FS1030	.076	.070	.0731	.001	.006	.0030	.0040	.0030	.0020	.004
FS1031	.080	.071	.0758	.001	.009	.0030	.0050	.0030	.0040	.004
FS1032	.077	.070	.0738	.001	.006	.0040	.0050	.0030	.0020	.005
FS1033	.075	.068	.0718	.001	.006	.0040	.0030	.0020	.0020	.003
FS1034	.076	.069	.0726	.001	.007	.0030	.0040	.0020	.0010	.006
FS1035	.074	.070	.0723	.001	.004	.0020	.0030	.0020	.0020	.006
FS1036	.076	.072	.0736	.001	.004	.0030	.0040	.0020	.0010	.003
FS1037	.073	.071	.0718	.001	.002	.0010	.0030	.0010	.0010	.005
FS1038	.078	.072	.0746	.002	.006	.0030	.0030	.0010	.0020	.003
FS1039	.078	.071	.0744	.001	.007	.0030	.0030	.0020	.0010	.010
FS1040	.076	.072	.0738	.001	.004	.0020	.0020	.0010	.0020	.003
FS1041	.075	.071	.0731	.001	.004	.0020	.0020	.0010	.0010	.002
FS1042	.078	.073	.0750	.001	.005	.0020	.0030	.0020	.0020	.006
FS1043	.078	.072	.0741	.003	.006	.0030	.0030	.0040	.0030	.006
FS1044	.074	.070	.0718	.001	.004	.0020	.0030	.0030	.0010	.011
FS1045	.078	.071	.0743	.002	.006	.0010	.0050	.0030	.0020	.003
FS1046	.073	.070	.0713	.001	.003	.0020	.0040	.0020	.0020	.002
FS1047	.078	.072	.0751	.001	.006	.0020	.0040	.0030	.0010	.004
FS1048[3]	.080	.075	.0722	.002	.005	.0020	.0050	.0020	.0020	Note 3
Avg.	.0771	.0712	.0739	.0013	.0058	.0024	.0038	.0021	.0018	.0050
Std. Dev.	±.0028	±.0014	±.0017	±.0002	±.0018	±.0008	±.0009	±.0009	±.0008	±.0028

Notes:
1. Lower datum is .484 inch above base; upper datum is 2.29 inches above base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Held for display.

Table VIII
Penetration Data
Effect of Standoff
DRB706 75 mm. Cones

Round No.	Comp. B lbs.	Standoff inches	Penetration inches in M. Stl.	Max. Spread inches	Std. Dev. inches
FS1023	.88	5.0	13.50		
FS1024	.88	5.0	14.62		
FS1025	.92	5.0	14.75		
FS1026	.92	5.0	15.50		
			Avg. 14.59	2.00	±.82
FS1027	.88	7.5	15.56		
FS1028	.86	7.5	14.44		
FS1029	.88	7.5	15.56		
FS1030	.88	7.5	14.18		
			Avg. 14.93	1.38	±.73
FS1031	.86	10.0	14.88		
FS1032	.88	10.0	14.94		
FS1033	.90	10.0	15.94		
FS1034	.90	10.0	16.38		
			Avg. 15.54	1.50	±.74

Notes:
1. Cones assembled in DRC505-1 test bodies, plugs and rings (No. 2).
2. Loaded at Ravenna Arsenal, BAT Lot No. 30, with Compostion B from Holston Lot No. 4-1197.
3. All rounds were tested at 0 rev/sec at Erie Ordnance Depot.

Table IX
Penetration Data
Effect of Rotation
DRB706 75 mm. Cones

Round No.	Comp. B lbs.	Rev/Sec	Penetration inches in M.S.	Max. Spread inches	Std. Dev. inches
FS1023	.88	0	13.50		
FS1024	.88	"	14.62		
FS1025	.92	"	14.75		
FS1026	.92	"	15.50		
			Avg. 14.59	2.00	±.82
FS1035	.90	30	13.00		
FS1036	.90	"	12.06		
FS1037	.88	"	12.50		
FS1038	.88	"	11.62		
			Avg. 12.30	1.38	±.59
FS1039	.88	60	7.69		
FS1040	.86	"	7.25		
FS1041	.88	"	7.18		
			Avg. 7.37	.51	±.27
FS1042	.92	90	6.18		
FS1043	.90	"	6.00		
FS1044	.88	"	5.50		
			Avg. 5.89	.68	±.35
FS1045	.88	120	5.81		
FS1046	.88	"	5.25		
FS1047	.86	"	4.62		
			Avg. 5.23	1.19	±.59

Notes:
1. Cones assembled in DRC505-1 test bodies, plugs and rings (No. 2).
2. Loaded at Ravenna Arsenal, BAT Lot No. 30, with Compostion B from Holston Lot No. 4-1197.
3. All rounds were tested at Erie Ordnance Depot using a standoff of 5.0 inches.

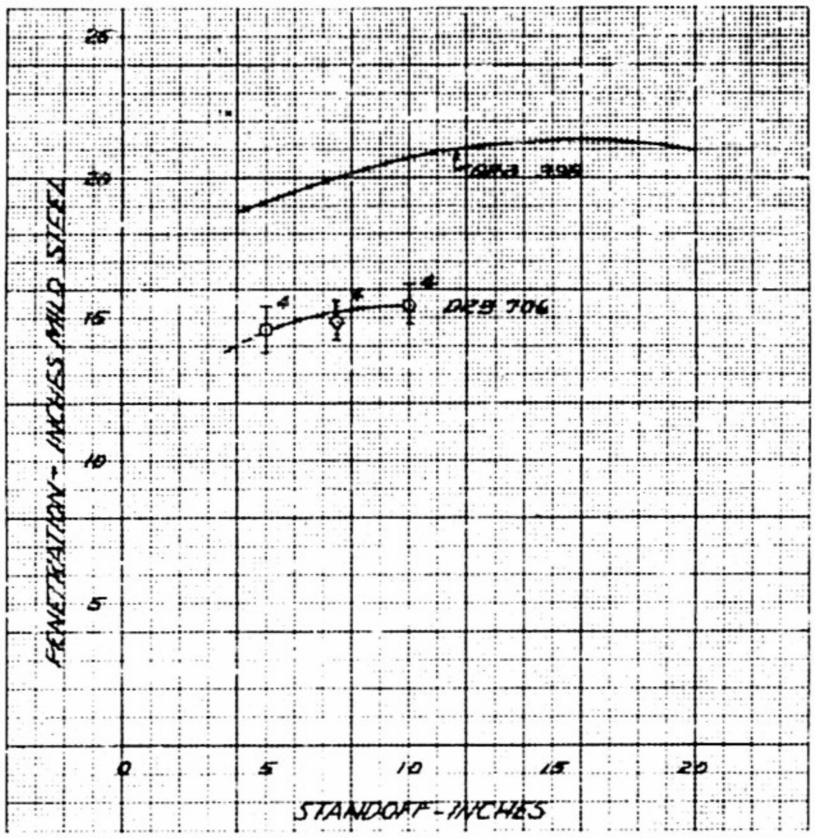

Fig. 8. Penetration Versus Standoff.
DRB398 (105 mm.) and DRB706 (75 mm.) Cones.

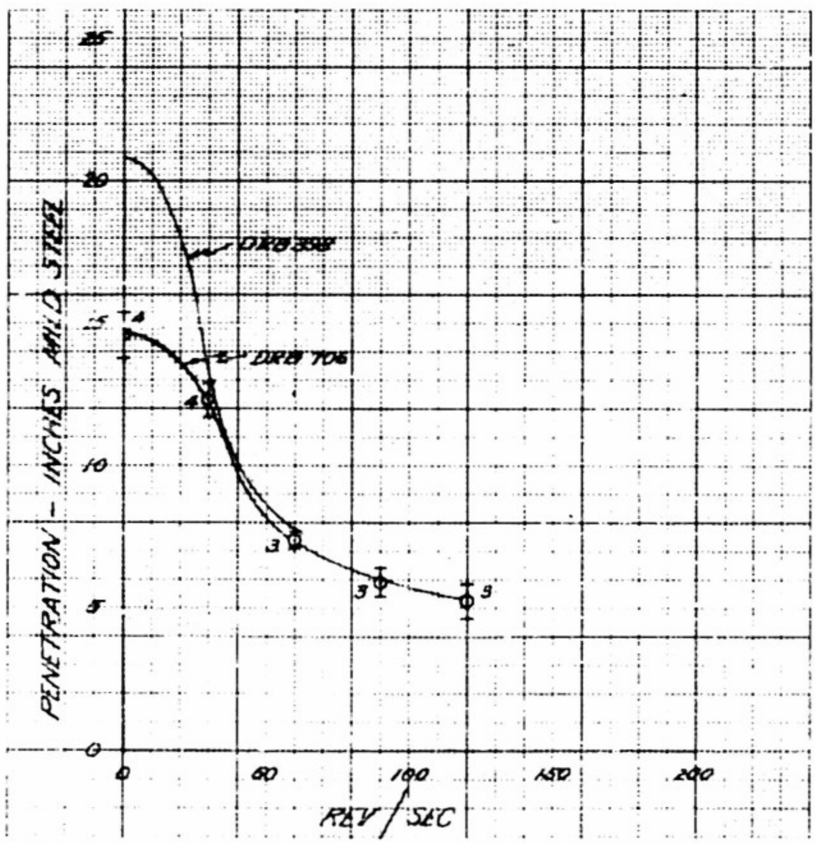

Fig. 9. Penetration Versus Rotation.
DRB398 (105 mm.) and DRB706 (75 mm.) Cones.

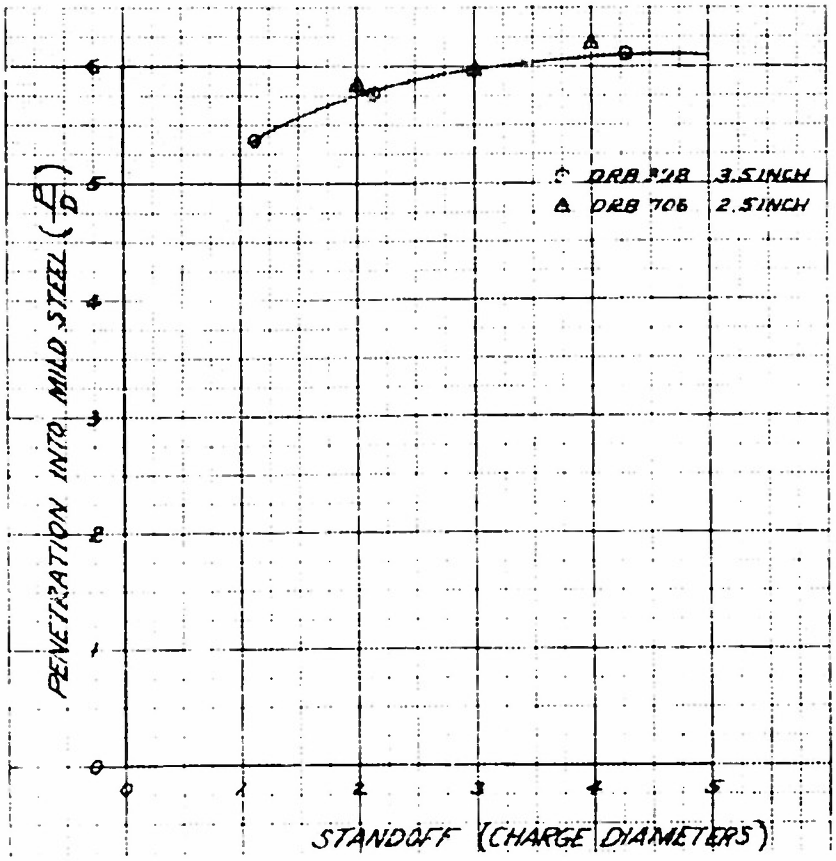

Fig. 10. Penetration Versus Standoff.
In Terms of Charge Diameter.

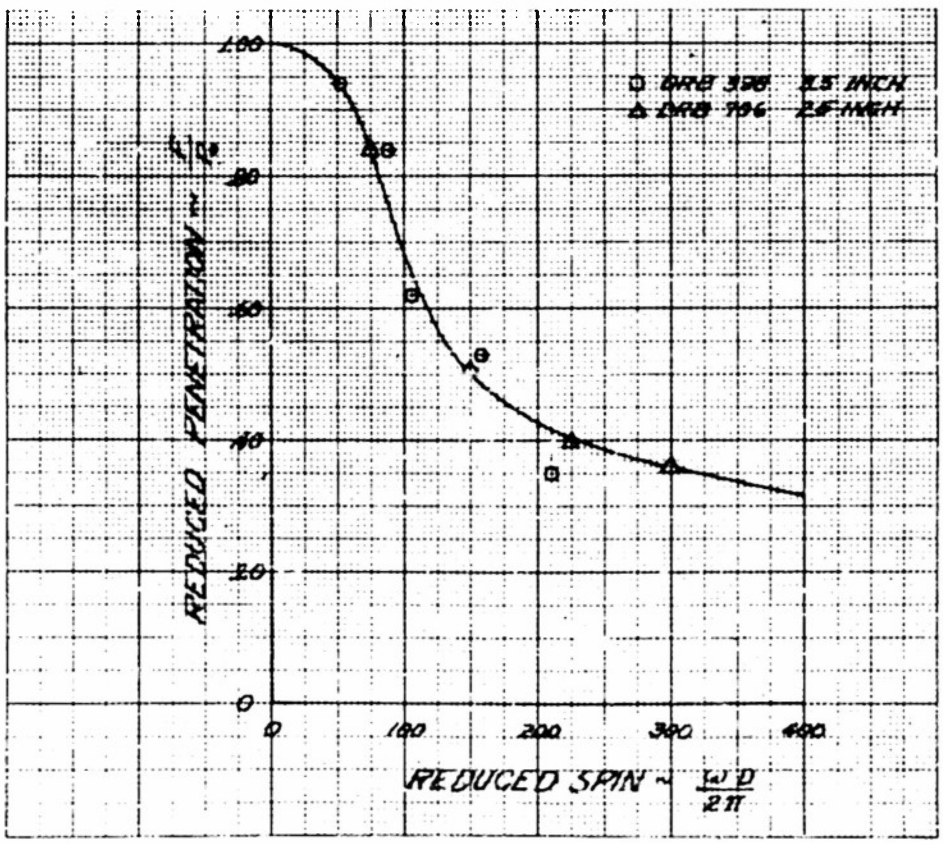

Fig. 11. Penetration Versus Rotation.
In Terms of "Reduced" Penetration and Spin Rate

Testing T267 Type Base Elements

The T267 type fuze combines both superquick and delay functioning. The development has been reported in the Thirtieth, Thirty-First and Thirty-Second Progress Reports. Further changes in design have been made and the tests have been continued.

Sixty T267 fuze base elements were made in accordance with DRD439 (Figure 12) and twenty have been tested in T138 E57 type projectiles equipped with spotting charges. The target consisted of a four inch thick wooden bursting screen located at a range of 200 yards.

Ten projectiles were equipped with barium titanate nose elements and were tested for superquick functioning. The remaining ten were not equipped with crystals and therefore any functioning of these rounds is presumed to occur as a result of the delay inertial element in the fuze. The firing record is shown in Table X and the data are summarized below.

The tests are being continued in an effort to determine the cause for the failures to function.

	With Crystal	Without Crystal
No. functioning superquick	4	--
No. functioning inertia	1	7
No. Failures to function	2	2
No. Doubtful Functions	--	1
No. Misses	3	--
Total	10	10

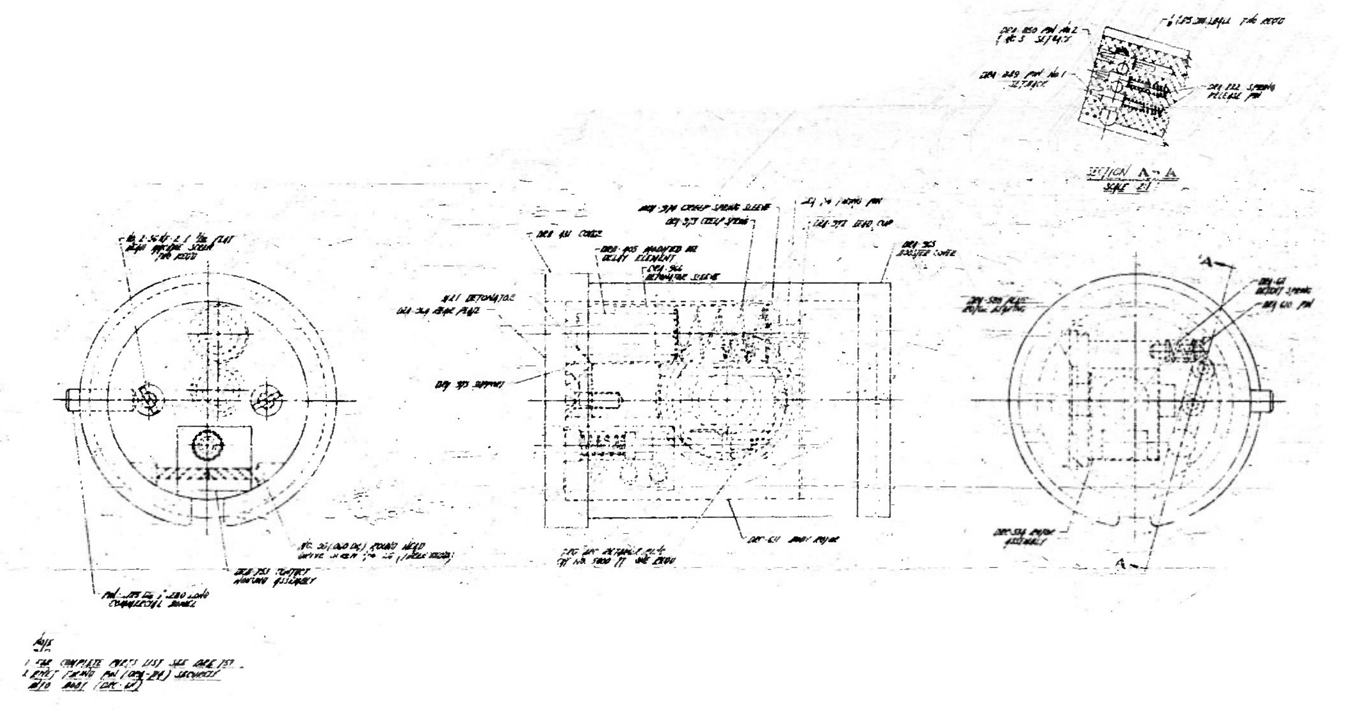

Fig. 12. Fuze Base Element, T267.
Firestone Drawing No. DRD439.

Table X
Firing Record
Evaluation of T267E14 Fuzes

(Gun) — 66' — 94.33' — 439.67' — 4 in wooden Bursting Screen

Purpose of Test: Evaluation of T267E14 Fuze
Program: 22

PROJECTILE
Model: T138
Type: ES7
Weight: —
CG Location: —
Bourrelet Dia: 4.132 .001

Date of Test: June 30, 1953

TEST GUN
Model: T137E3
Type: 105mm Recoilless
Serial No: #1
Chamber: 22-B 775 R #1
Bushing(Vent): 22B 82 X-D
Tube: 22-C-444 D 1 in 20 Twist
Sighting Equipment: M17 Adapted Telescope
Mount
Type: Pendulum
Constant: 2.48 lbs Sec/in
Solenoid Fired Mechanically

MISCELLANEOUS DATA
Range: 200 yds. 4 in Wood Bursting Screen
Propellant
Type: MP M10 Web .033 Weight 7 lbs 14 oz
Lot No: PA 30239
Primer: M53
Shell Case: T53E1
Liner: Polyethylene
Temperatures
Magazine Max 70°F Min 70°F Present 76°F
Loading Room — Ambient 92°F

Round No *	Proj No	Proj Weight (lb)	Powder Charge (lb - oz)	Recoil	Fuze Type	Muzzle Velocity ft/sec Instr	Actual	Elev (mils)	Observations
5195	11	17.19	7 - 14	7 1/2" F	Super Quick	1687	1715		Missed bursting screen
5196	12	17.30		6 1/2" F		1683	1711		Failed to function
5197	13	17.19		9 1/4" F		1689	1717		Functioned at screen
5198	14	17.17		10" F		1687	1715		Functioned at screen
5199	15	17.22		7" F		1697	1725		Functioned at screen
5200	16	17.25		7 3/4" F		1680	1708		Functioned behind screen
5201	17	17.24		9" F		1684	1712		Missed bursting screen
5202	18	17.38		13" F		1556	1684		Failed to function
5203	19	17.18		8" F					Missed screen or through a hole
5204	20	17.22		9" F		1683	1711		Functioned at screen
5205	1	17.20		8 1/4" F	Delay	1700	1728		Functioned delay
5206	2	17.16		9" F		1671	1699		Failed to function (May have functioned 3 mi out) at which smoke observed
5207	3	17.23		16" F		1652	1680		Functioned behind target screen
5208	4	17.17		8" F		1693	1721		Failed to function
5209	5	17.20		5" F		1720	1748		Failed to function
5210	6	17.18		9 1/2" F		1683	1711		Functioned approximately 300 yds behind screen
5211	7	17.22		9 1/2" F		1677	1705		Functioned approximately 300 yds. behind screen
5212	8	17.15		5" F		1687	1715		Functioned approximately 10 ft behind screen
5213	9	17.16		6 1/2" F		1703	1731		Functioned 50-60 yds. behind screen
5214	10	17.11		10 1/2" F		1668	1696		Functioned approximately 300 yds. behind screen

* All rounds were loaded & fired as single units. No wadding was used.

Proof Director: J. Chaney
Observers: W. Russell

Signed: O. Miller

MANUFACTURING SUMMARY

In addition to the experimental material prepared for the research and development work under contracts DA-33-019-ORD-33 and DA-33-019-ORD-1202, described in preceding progress reports and in the preceding pages of this report, the following have been manufactured and shipped to the installations indicated. Firestone's Defense Research Division, in shipping these items, transfers custody and control of the items to the receiving agencies. However, personnel of Defense Research Division will continue to collaborate with personnel of the other installations.

I. Cartridges, T119E11, Metal Parts Assembly, w/o Fuze T208E7

Prior to June 1, 1953	4430	All Shipments
June 1, 1953	300 (Live)	Milan Arsenal
June 2, 1953	30 (Live)	Picatinny Arsenal
June 5, 1953	300 (Inert)	Milan Arsenal
June 11, 1953	300 (Inert)	Milan Arsenal
June 18, 1953	300 (Live)	Milan Arsenal
June 26, 1953	300 (Inert)	Milan Arsenal
June 26, 1953	25 (Live)	Picatinny Arsenal
Total to June 30, 1953	5985	

II. Rifles, T170E1 for ONTOS

Prior to June 1, 1953	6	Aberdeen Proving Ground
June 13, 1953	6	" " "
June 22, 1953	6	" " "
June 23, 1953	6	" " "

III. Mounts, T149E3 for ONTOS

June 1, 1953	1	Allis-Chalmers

IV. BAT Systems, Less Jeep (T170E1 Rifles, T149E3 Mounts)

Prior to June 1, 1953	2	Aberdeen Proving Ground
June 2, 1953	2	" " "
June 8, 1953	1	" " "